A Distributed Elderly healthcare System

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Abstract. The recent advances of ICT allow developing new generation of tele-homecare systems to enable elderly health monitoring and management and ease their daily life. Such a system can reduce the amount of admissions to hospital, facilitate more efficient clinical visits, and may replace a hospital stay by living at home. In this paper we present a patient oriented distributed tele-homecare system, by which we created a new concept of building smart home by integrating telemedicine and home automation systems.

1 INTRODUCTION

As the population grows older, people becomes increasingly dependent as their sensory, motor and cognitive physiological health capacities deteriorate; these age-related changes, are amplified if they are accompanied by pathological conditions (e.g. osteoporosis, osteoarthritis) that are common in the elderly population. Most European countries are now facing an urgent requirement to provide appropriate retired home environments solutions for these citizens and allow them to play a role in our society. Elderly requiring healthcare services must move to distant medical centers and this is often not feasible due to their state. Elderly tele-healthcare systems can be achieved using advanced communication networks and Internet technologies. These technologies have a key role in the development of a telehealth system and smart homes.

Healthcare integrated smart home allows the tenants and their family members to benefit from a safe home environment with activities and services accompaniment for their daily steps. In order to reach that goal, we aimed at several technologies and implemented them in a demonstration prototype apartment. Several issues on objectives and contributions of technologies were stressed out [1]:

- Enhance independent living with cognitive assistive systems [2].
- Provide safety and security to inhabitants with the help of medical services supervision; monitor general activities of the occupants [3] and monitor unusual routines or abnormal behaviors that reach dangerous levels [4].
- Improve social contact and cultural activities within the elderly surrounding thanks to communication systems and appropriate equipment [5].

- Engage medical actors to use computerized systems in order to ease information processing and traceability.

For these reasons, elderly tele-homecare, videoconferencing and tele-consultation systems have been attempted by many researchers. Many telemedicine and e-health systems are being developed and many innovations and ICT-based emerging solutions are close to be operational, nevertheless the expected take-up did not occur yet, since proposed systems and their targeted medical benefits are certainly too segmented and disconnected the ones from the others. In addition, most of existing products and services in this field rely on proprietary technologies, which is a substantial obstacle to the development of complementary services or applications, and thus of the market. Consequently, population like elderly, disabled people or chronically ill people, who are often suffering from co-existing troubles, are not encouraged to dare benefiting from ICT and innovations, as available solutions are not complete, not compatible the ones with the others, not scalable, neither end-to-end nor comprehensive, and remain then unaffordable for someone who would try to subscribe to each relevant service covering a more or less significant part of its medical and social needs, without ensuring a global management of the daily problems. The current developments and innovations are limited in terms of commercial and operational perspectives and suffer from certain phenomena:

- The fragmentation of experimentation, projects and products did not yet give birth to any efficient and affordable holistic solution that could fulfill the various targeted beneficiaries and users' expectations.
- The development costs and R&D expenses required for a proper adaptation to each community of users and beneficiaries' needs make investment very high, as time-to-market delays are uncertain and no business model has been successfully assessed yet in this domain.
- The accompanying measures, at institutional, ethical, legal, financial and organizational levels remain insufficient, which prevent the development and the sustainability of such assistance and at-home monitoring services.
- Finally, the population is neither confident nor familiar enough with these innovation-based solutions, especially in such a medical or health-related purpose, although their development requires that they become a natural component of the medical and social environment and infrastructure.

2 State of the art

A telehealth application is a complex system that requires the integration of various sub-systems and applications. As we said, nowadays, many telehealth and e-Home applications are available; however, it is difficult to find the system that matches exactly the end-user requirements.

In [6] the authors presented a teleconsultation system. This system is based on web technologies and the user accesses the system over the Internet or an intranet. The system therefore is designed to do a teleconsultation, and it is not integrated with the other healthcare modules or an automatic analysis of patient's health situation.

TOPCARE [7] is a telehealth system for mobile care and homecare of high risk patients, elderly and care needing people. The system is an open telecare platform solutions for telemedicine services. The overall objective of TOPCARE is to develop technical devices and telecommunication structures and to lay the organizational groundwork for bringing co-operative health care services into the home of patients. System comprises a telematic homecare platform (THP) backbone, the development of telematic home stations (THS) and health professional stations (HPS) and a communication server that will manage the network administration, the health professional registration at the THS, the device communication, and the Internet access. Therefore, in TOPCARE, interaction is limited to only the clients having TeleHealth Client (THC) module.

The Interactive and cooperative tele-monitoring of the dialyzing at home (DIATELIC) is a system of tele-monitoring of dialyzing at home by the technology of DPCA (Dialyze Peritoneal Continue Ambulant) [8]. It was developed by LORIA in cooperation with the doctors of the ALTIR (Lorraine Association of Treatment of Renal Insufficiency) and a doctor advice of the Health insurance. Research works drove to the Diatelic system. This system is only designed specially for the dialyze patients.

The AFIRM team of the laboratory TIMC-IMAG in Grenoble developed a project called System of Information and Communication of the Inteligent Home for Health (SIC - HITCH) [9]. Objective is to monitoring the patient in his home with sensors installed in his home, by triggering off alarms in the appropriate urgent centers, in case of feelings of faintness, in falls or in abnormal situations. This system is an experimentation and simulation platform.

3 System architecture

The requirements presented in the previous sections and remaining obstacles or brakes make the design of monitoring and assistance tools quite complex, as each pathology or disability generates its own set of requirements and constraints. Such context increases the need for the development of innovative global ICT-based solution allowing to implement personalized and person-centric care process and tools, which can evolve with the users' medical and social and physical evolution, and which can compile the various collection and analysis of data to ensure a reliable and sound diagnosis, medication and evaluation of the medical and social state of the person.

To reach these advantages, we developed a patient oriented tele-homecare system. By a user requirement analysis, we propose a Multi-tiered architecture (see Fig. 1). The elements of this architecture are:

- Medical Sensors (and / or Body Sensor Network (BSN)): This part consists of the medical instrumentation important to patients medical monitoring. As the studies show [1], for 65% of the elderly, this is not acceptable to attach theme any sensor, for this reason we use a noninvasive medical monitoring, but for the exceptional cases that we need to have a real-time monitoring of their medial state, we use Body Sensor Network. This network consists of very small portable devices equipped with a variety of sensors for medical monitoring, patient localization and identification.

- Environmental Sensors and Home automation sensors network: This network must include sensors unfolded in environment (rooms, halls, WC …). These sensors can include those of the temperature, humidity, movement, acoustics, the camera, etc.
- Gateway: It may be the mini PC installed in each home, or a mobile system such as a PDA. It connects body sensor network and also environmental sensors like home automation sensors and actuators to the Internet. It also includes intermediate receivers, assuring an efficient data transmission. In this part we have some preprocessing of the data received from medical and home automation sensors, to detect urgency anomalies.
- XML data exchange by using web services technology: This system uses web services to interact between the client and the server, as shown in Fig. 2 This system has intention to address the need to standardize the transmission of physiological data, by using the platform independence of web services and the structural independence of XML in the development of a web service for data transmission, processing and storage of physiological data for the service of tele-monitoring. By using web services, the system requires minimal additional technological elements and minimal technical requirements of support.
- Graphical User Interfaces. We designed a very easy-to-use graphical user interface. This interface is commendable by using a PDA or TV remote controller.

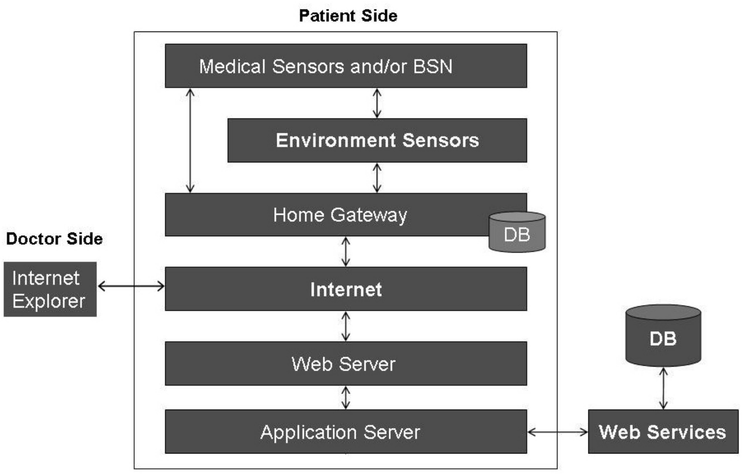

Fig. 1. System's general architecture

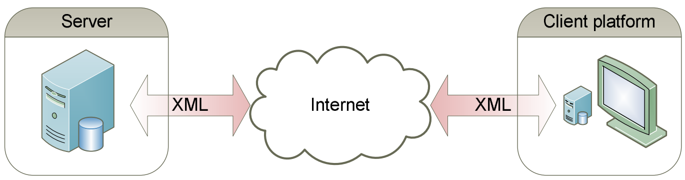

Fig. 2. XML Data exchange

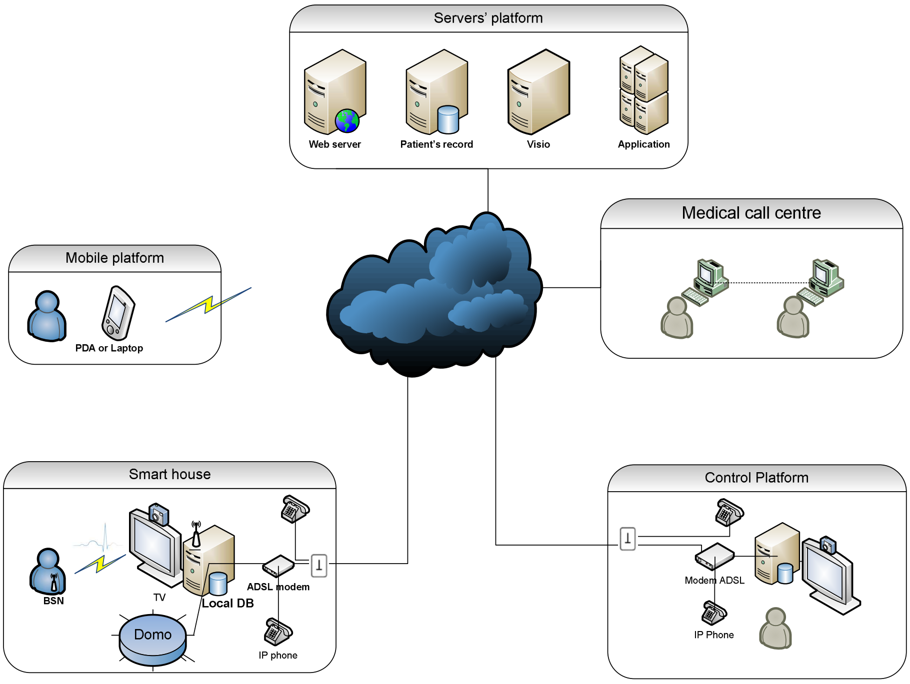

Fig. 3. Different platforms

This system interfaces to healthcare providers, doctors, care-givers and the medical call centers (See Fig. 3) and also is integrated with a mobile platform for the occupant to remote control his home and another mobile platform for the doctors and nurses to view the state of their patients. Typically they will receive an alarm in case of a health problem of their patients.This figure shows that the system is integrated with vital sign monitoring devices and sensors. The system has possibility of integrating the system with the wireless devices and sensors with different communication methods such as Bluetooth, ZigBee, USB and the other technologies. The medical data are store in the database aromatically; without any manual action. We aim in this project to integrate ZigBee protocol with home automation protocols, such as KNX, IHC. Among the many wireless technologies, ZigBee is one of the most promising ones for home automation; a wireless home networking system can be configured using ZigBee alone [10].

4 Functions and features

The main objective of this project is to develop a universal user-oriented healthcare system to allow elderly to be medically monitored and assisted in their home. The benefits and added-values of the proposed system and service are to offer a continuous medical monitoring of the person's health combined with a permanent watch of the immediate dangers in the person's home: the automated alert system will contact a video call center able to evaluate the emergency level of the alert and to contact the most relevant assistance (like relatives, doctors, carers or emergency services). The continuous follow-up of the evolution of the medical state allows detecting automatically the potential deterioration of his/her health, thanks to biomedical sensors adapted to the person's specific pathologies, and thanks to actimetry and situation detection systems. The automated alert system will then send an alarm to the supporting call center in case of deterioration of the health parameters or detected immediate dangers, like fire and flood. The service will also ensure an automated monitoring and alert system for the detection of falls and abnormal behavior according to the localization, activity, condition and habits of the person.

This solution's advantage is to propose a global system, accessible from anywhere, displaying an adapted remote sensing service combined with interactive telecommunications and an automated alert system. The innovative feature of the system regard two main axis: the high level technological integration of several innovative modules to be interconnected and correlated, on the hand, and the challenging conception of an adapted and sustainable service from end-to-end, with the overall management of the value chain involving the industrials – who develop, adapt and integrate technical products and services- the service providers and operators – who define and implement new models and structures for the delivery of services from the call center up to the distribution of the offer, and finally, the users and beneficiaries of such services, including the patient, its carers and relatives – who integrate this new habits and tools into their daily life and environment and provide their feedback on each brick of the overall solution and its concrete organization. These two main innovative issues resulted into a real challenge in terms of services, as to whole project’s conception involves the users and the involved actors, so as to well define and adapt each element to turn into a success factor in terms of acceptance.

4.1 Technological innovation:

The technological innovative activities and technical challenges addressed in the system are as follows:

4.1.1 Distributed patient record

As shown in Fig. 3, the patient record has a distributed architecture, and we have a local database in each client computer. We used a distributed patient record because in distributed database architecture the data is not stored entirely at a single physical location. Instead, it is spread across a network of computers that are geographically dispersed and connected via communications links. We have therefore a large database capacity and incremental growth, and like all distributed databases, we have a reliable, available and flexible database. The most important advantage of a distributed database for our system is that a distributed database allows faster local queries and can reduce network traffic.

In this system, in each client computer we have a pre-processing of patient’s data to detect the eventual emergency problems. This distributed database architecture helps to early detection of emergency problems, that means by checking the local database, if the data from healthcare devices are outside the ranges defined in their care plan, or if the data have not been received when expected, the system will trigger an alarm that may result in an automated connection with a medical call centre.

On the other hand, by using the data from home automation sensor and medical devices, the application stored in the web server, will analyse the medical record by using intelligent methods like Fuzzy Logic or other more complex cognitive systems, to find the potential health problem. By detecting a problem, the system will trigger an alarm that may result in an automated data transmission to a doctor.

4.1.2 Activity monitoring by Home automation system and with/without BSN

The system gives not only to the patients a full control of Home automation devices, by using system’s simplified interface (Fig. 4) but also generates the alerts by using home automation sensors, which allow an indoor localisation of the beneficiary and can, thus, propose a fall detection service generating alerts. The system allows doctors or healthcare providers to measure the physical activities of elderly. The system uses a more passive method. It senses a person’s presence in a room by home automation sensors installed throughout the living areas, such as motion and presence detectors, light, magnetic and temperature sensors. Activity patterns are then analyzed in the local computer for unusual behavior in activities and also to fall detection, which use an intelligent method by using Fuzzy Logic. All the results save in a database and the system in its learning period will use this database to person’s behavior modelling to reduce number of false alerts.

Fig. 4. Home automation interface

4.1.3 Video conferencing and Tele-consulting

Tele-Healthcare is related to offer health care services over Internet or a wide area network, and in this domain, videoconferencing is one of the important solutions, allowing real-time interaction between patients and the Doctors. The offered system is integrated with a simplified and user-friendly videoconference system which is adapted to use in elderly tele-Healthcare. This sub system is used to have a video meeting by the families and also to request an online consulting; in this case the in the first step, the patient requests a medical visit by connecting to videoconferencing system. System sends a message to doctor and loads patient's medical record. Doctor joins the conference and by ending the consultation, fills a form and saves it to medical record and ends the consulting. Finally, the system creates a billing and sends it to patient. Patient can view the billing in his interface and pay it online.

4.1.4 Integration with other home or health systems

Integration of several innovative modules into a global and interoperable network of networks and systems is a grate innovative point in our system. The client side system is a media centre module to facilitate usage of TV and easy access to video and music sources. Figure 5 shows the client side system architecture. In this system, we used a modular architecture to facilitate integrating of the optional module and also to provide an easy procedure of updating and maintenance.

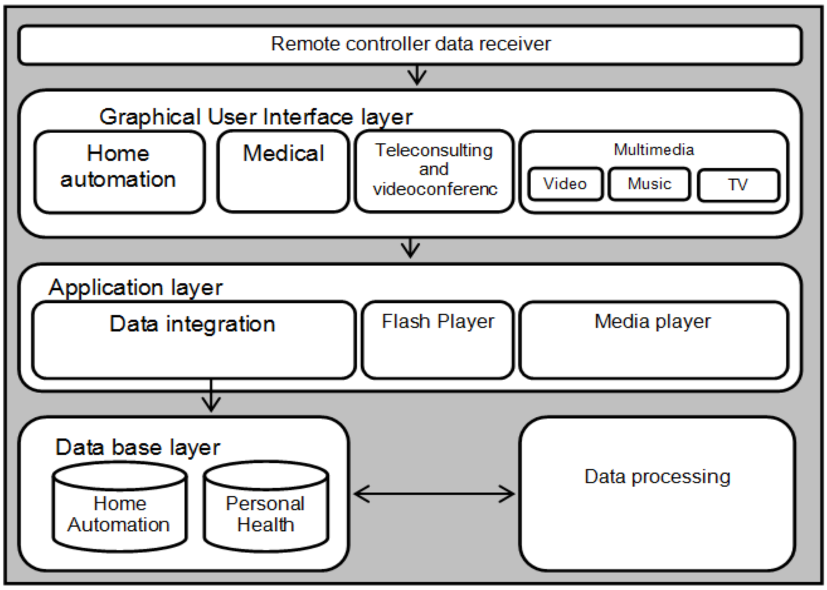

Fig. 5. Client side atchitecture

4 Conclusions and discussion

In this paper, we have presented a distributed system to support remote medical consultations and elderly management and homecare across global wide area networks and heterogeneous platforms.

A flat is entirely equipped to act as demonstrator and as laboratory and our system is under final testing there. We use this flat to evaluate our system and also the different algorithm that we proposed during this project, the algorithms like clustering and indoor localization in sensor networks [11] and fault management in these networks.

By using this system, MEDeTIC (*www.medetic.com*) , a non-profit organization, offers a new concept of building smart homes by using telemedicine and home automation, named in French “Maisons Vill’Âge®”. The first houses are in building with basic implements of data acquisition and human-machine interface.

In this type of systems, several challenges need to be addressed. The technological challenges regard the generic features of the dynamic database, of the wireless sensor networks, of the different supporting platforms, of the video call centre, and web services, to allow a flexible and smooth interaction among those items and to anticipate further additional functionalities, interacting devices, and so on. In this respect, the methodology of specifications, development and integration of the technological features must be realized with a major concern for some important concepts, like: Interoperability, Scalability, Evolution and customization according to the users’ medical and social profiles and needs.

On the other hand the design and integration effort for the technical and R&D activities of the project focus on the design of services and interfaces ensuring a maximum level of natural understanding on the way to use them, that is to say with an enhanced effort on the prerequisite and experimentation feedback’s of the users who are suffering from chronic conditions and are not familiar- and sometimes reluctant- with ICT and innovation-based devices and systems. Ergonomic interface, accessibility, scalability and evolutionary solution according to the evolution of the users’ needs are the important aspect of development.

Another important point is QoS (Quality of Service) requirements, like availability and response time. As the healthcare industry is turning to information technology to help solve its business issues, specially provide to quality patient care services, it is important to develop QoS specification in distributed health information systems [12]. Unlike traditional systems, many non-end-to-end mission-critical applications envisioned for healthcare systems, which are complex systems, because in these systems, we can find different subsystems, such as, wireless sensor networks, LANs, software platforms, home automation systems, mobile systems, Internet… that require different QoS requirements on the system, and these requirements pose unprecedented challenges in the area of QoS support in healthcare systems.

Our first study shows that all the healthcare professionals have a positive attitude toward dedicated means for ICT practical application (50% “totally agree”, 33.3% “strongly agree” and 16.6% “lightly agree”). Majority of interviewed elderly residents, in this study, declare not knowing what would be their family attitude toward ICT use (45.83%); 37.5% think that their family would be favourable to ICT use and 16.67% think that the family would be unfavourable to ICT use, but this study with the projected family attitudes of elderly people shows that the limitations experienced in everyday life do not lead to a favourable or unfavourable category of ICT user [1].

Any failure or lack of performance on the system which could not be tackled in a reasonable delay may have some damageable consequences on the solutions' acceptance and development potential: the confidence is a basic and elementary factor of acceptance or reject, such incident could also generate a psychological defiance towards ICT's in general and towards such innovative assistance and monitoring services. For these raisons, as our future work, a middleware will be developed to give a dynamic and intelligent QoS to the system.

Due to the results of this first study, definition and revision of planned applications (scenarios improvement), behavioural intention and acceptance of designed implemented solutions and finally actual usage and acceptance evaluation will be our future work.

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